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RATIONAL CHARGING EQUIPMENT FOR BLAST FURNACES

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Basic parameters of the charging practice in a blast furnace, namely the location of the stock line, weight of the coke charge, and the method of charging, lead to the maximum utilization of the thermal and chemical energy of the gases through a rational organization of the gaseous stream.

Practical experience has demonstrated that, for obtaining a uniform and stable furnace operation, the distribution of the gaseous stream, determined by the changes in composition of the gas along the diameter of the upper level of the charge located 3-4 meters below the edge of the big bell, must be characterized by the minimum concentration of CO_2 at the periphery (5-7%), an increase of it in the intermediate zone up to 15-20%, and a drop in the axial zone to 5-10%.

Conventionally employed alternation of charging ore first or coke first in order to change the character of the gaseous stream (changing it from the peripheral to axial) frequently fails to achieve the desired results. When pulverulent ores having a low bulk density are used and when the volume of ore in a round is larger than that of coke, one cannot obtain, for example, an axial flow, since the material is redistributed at the top with the transfer of the fine fractions to the axial zone of the furnace.

Improvements in the preparation of the raw materials assist the perfectioning of the technology and controlling the gas distribution by programming the charging, but even such a control does not always bring the desired results.

Gas distribution depends in the first place on the structure of the column of the charge materials determined not only by the properties of the ores being smelted and of coke, but by the character of the column motion as a whole, redistribution of the materials on the surface of the charge, and the displacements of particles inside of the column during its descent.

During the descent of the column and falling of the materials from the big bell a redistribution of the materials according to their size takes place within and on the surface of the column. As a result of this, a specific gaseous stream is established, the character of which is greatly influenced by the granulometric composition of the charge, furnace lines, and the rate of melting.

Blast furnace men always strive for a uniform horizontal and an optimum vertical distribution of the materials and, therefore, for an optimum distribution of the gaseous stream in the horizontal cross section.

Methods for controlling the horizontal distribution of the materials can be reduced to different changes in the program of rotation of the McKee hopper. For controlling the vertical distribution, mostly changes in the charging system are used, less frequently of the stock level and the size of the rounds.

A. <u>Distribution of the materials at the top.</u>

Distribution of the materials at the top before blowing-in substantially differs from that observed in a working furnace.

When materials fall from the big bell in the absence of blasts they follow the conventional laws of the segregation of fractions according to the size. Depending on the height of the stock line, the ridge of the small fractions of the materials approaches the wall of the furnace, at a certain height reaches it, and then digresses from it. The zone of the contact of the fine fractions with the wall is found at the 1.2-2.5 meter level, i.e., at the conventional level of the stock.

Checking this statement on a model furnace, Figure 1, in which all dimensions were reduced to one tenth with a corresponding reduction of the lump size completely verified the dependence of the ridge location from the stock line level, as well as the contact of the small fractions with the wall at the 1.2-2.5 meter level, Figure 2. On descending of the materials in the furnace, coke forms an angle of repose of 30-32° and ore of 26-33°.

Many measurements of the profile of the charge at different levels in a working furnace have shown that no ridge of materials is formed under these conditions, the character of the charge surface depends above everything on the granulometric composition of the charge, the components of which are distributed at a smaller angle of repose than when no blast is used. Depending on the screen analysis of the ore, the angle of its repose changes from 0 to 20° and that of coke from 18 to 25°. Pulverulent ores falling from the big bell practically do not form any angle of repose on account of the redistribution of the fine fractions, Figure 3.

When working with a burden having a low bulk density which contains a large proportion of 3 mm max. fraction, the axial zone of the furnace is overcharged with ore with a corresponding increase of CO_2 in the gas. In order to determine the mechanism of redistribution of the material occuring in this case, a systematic study has been conducted of the materials distribution at the top by lowering weights on the stock line through the measuring pipe. Distribution of every individual material has been checked using a large number of measurements.

As a result of this, it has been established that the materials of the charge are distributed at the top in a funnel-like fashion without forming a ridge next to the wall. When light and fine materials are falling from the big bell, the upward stream of gases supports them from below rendering the trajectory of their fall flatter.

The motion of gases changes also the character of distribution of the different materials already fallen on the stock line, and this is shown by average results of 6-10 measurements of their angles of repose directly after the functioning of the big bell, Figure 3.

The distribution of the fine ore does not follow any laws. Its angle of repose in an operating furnace changes as follows, Figure 3:

Charging system	CCOO	COL	0000 x CCCx
Angle of repose of fine ore	-6°40'	3°50'	13°20'

On account of a frequently formed suspension of the materials (a loosened layer) the lowered weight sank in the loosened layer; in this case as the level of the charge was taken the level of the contact point.

At the moment of the discharge of materials from the large bell, the upper layers of the charge were condensed and settled down, but already after a minute's time the suspended state of the materials was restored.

During the subsequent motion of the materials, a further horizontal redistribution takes place in the column of the charge and the formation of a corresponding gaseous stream.

Under the present conditions of controlling the gaseous stream, loosening of the periphery or of the central zone is achieved by a special charge of ore and coke in these areas. On this account, the distribution of the fractions of the charge along the cross section of the shaft must be done in the very process of forming the surface of the charge, which does not always lead to a uniform horizontal and an optimum vertical material distribution.

In order to obtain a uniform distribution of materials on the surface of the charge, the charging equipment must be improved so as to achieve the discharge of materials with the minimum horizontal displacement.

This is possible only when the charging device meets the following requirements:

a. an optimum distribution of the materials on the surface of the charge column, both in respect to the uniformity of the charge components and their size;

b. reduction (elimination) of the secondary materials redistribution after charging a round in the furnace;

c. uniform charging of the materials on the surface of the burden, while eliminating wide variations of gas pressure on lowering of the big bell;

d. charging materials on a constant level of the charge avoiding fluctuations of the height of the charge column in the intervals between lowerings of the big bell and of distortion of the charge surface;

e. possibility of an effective and steady regulation of the motion of gases in the column of materials to be smelted, in particular, regulating the CO_2 content in the gas;

f. assurance of a uniform and steady distribution of the gaseous stream along the diameter of the horizontal section and along the periphery of the concentric zones (CO_2 curves) with the optimum vertical distribution of the gaseous stream;

g. sufficient air tightness even when working under elevated top pressure;

h. automation of the blast furnace control and regulation of furnace operation by charging.

With the present charging devices which meet the requirements of gas tightness and strength, the control of the character of the gas stream and of its vertical distribution is effected by changing the order of materials placed on the big bell (alternating charging systems), a practice which not always has the desired effect when a redistribution of the materials takes place on the surface of the charge. The horizontal regulation of the gas stream by the changed program of the rotation of the distributer hopper and the inclination of the skips is not sufficiently effective.

The conventional charging devices do not assure depositing the materials only at a given level of the charge and do not provide the optimum distribution of the materials on the surface of the column.

With the existing distances between the wall of the top and the big bell the ridge of small materials reaches the wall, and on account of the concentration of fines next to the wall, there occurs a certain transfer of these fines from the periphery to the axial zone of the furnace which leads to a non-uniform horizontal distribution of the materials and, therefore, to a non-uniform gas stream.

With such charging devices the normal operation of a blast furnace depends to a large extent on the qualifications of the blower and of the furnace personnel.

B. Charging device of the new construction.

Inadequacy of the present charging practice compounded from the size of the ore and coke charges, charging system, stock level, and the program of rotation of the rotary distributer, is derived from the impossibility of establishing the influence of each of these parameters on the distribution of the materials at the top which is necessary for maintaining the constancy of this distribution, both from the standpoint of size and chemical composition. This impossibility can be explained by the effect of three factors:

a. non-uniformity of raw material from the chemical and granulometric standpoints;

b. effect of the gas stream on the distribution of the materials during their fall from the big bell;

c. the lack of reliable means for checking materials distribution.

Uniformity of materials distribution at the top can be effected only by elimination or reduction to a minimum of the first two factors. Under these conditions, controlling the furnace from the top is greatly simplified and the self regulation of the blast furnace operation becomes possible.

The solution of this problem is possible by a corresponding change in the design of the modern charging device so as to obtain a uniform distribution of materials already along the periphery of the large bell and by reducing to a minimum the effect of the gas stream on the materials falling from the big bell.

The design of the new charging device, Figure 4, has two objects:

1. Assuring a uniform, from the standpoint of size and chemical composition, distribution of the materials in the furnace (along concentric circles); this problem is solved by the charge distributer, Figure 5.

2. Assuring the constancy of the optimum vertical distribution of the materials in the furnace (along the radius); this problem is met by the charging device, Figure 6.

<u>a</u>. <u>Charge distributer, Figure 5.</u>

The rotary hopper <u>a</u> serves as a receptacle of the charge distributer; it rests on three supporting rollers б ; the radial loads are taken up by thrust rollers в .

The distributing bell г serves for assuring a uniform horizontal distribution of the charge on the big bell; bell г is connected kinematically with the rotating hopper <u>a</u> and the external drive of the charge distributer. The scheme presupposes the provision of an impulse for starting the drive at the moment of the beginning of the material transfer from the skip into the hopper.

The velocity of rotation of the distributing bell and hopper is assumed to be 12 R.P.M. which is sufficient for the discharging of the charge under the influence of centrifugal force. Prior to complete discharge of the burden, the distributing bell makes about 8 revolutions which eliminate both qualitative and quantitative non-uniformity of the charge occuring in the receiving hopper of the conventional charging device after the discharge of the materials from the skip.

The distributing bell rod is protected by two cast sleeves, the lower of which rotates with the bell and the upper one with the roller thrust bearing is suspended rigidly on two rods.

The small bell д serves for preventing gas escape during the lowering of the large bell; the step-wise flanging of the small bell practically eliminates the wear of the contact surfaces between the bell and the hopper.

The operating scheme of the charge distributer presupposes the provision of a lowering impulse to the small bell at the moment of the beginning of rotation of the distributing cone. On this account, the arrivalof charge always finds the bell in the open position.

The body or hopper of the charge distributer also has a step-wise flange on its lower edge at the point of its contact with the small bell. On the four brackets of the hopper are placed three supporting rollers 3 and one angle reducer ж . The three supporting rollers are mounted on roller bearings. The drive for rotating the charge distributer, Figure 4, consist of a 27 KW short-circuited electric motor rotating at 970 R.P.M. and a cylindrical reducer. The rotation is conveyed through the intermediary shaft and an angle reducer to the gear mounted on the rotating hopper.

b. Charging device, Figure 6.

The large bell a serves for feeding the charge materials into the distributing cylinder б and the formation of an air tight seal preventing the escape of gases when the small bell is open.

The hopper of the large bell в is the container of the space between the bells. The charge distributer is mounted on the gas seal.

The distributing cylinder 3 serves for assuring the constancy of the required distribution of the materials along the radius of the furnace and for maintaining a constant level of the stock line in the working space of the furnace.

The guiding hopper д permits changing the position of the ridge of the materials in the distributing cylinder. In Figure 4, (HB) is shown the first imperfect modification of the guiding hopper placed rigidly over the distributing cylinder. This does not permit changing conditions of materials distribution when the operating conditions of the furnace vary.

In Figure 6 is given a second modification of the guiding hopper equipped with a drive for displacing it in the vertical position. This permits changing the position of the materials ridge in the distributing cylinder and, therefore, the distribution of the materials in the furnace, Figure 6, A, Б, B. In this light it becomes possible to retain constant the size of the rounds, the system of charging, and the stock line level and to achieve the desired distribution of the materials, when the operating conditions change, by simply changing the position of the guiding hopper.

C. Testing the model of the charging device of the new design.

In order to investigate the performance of the new device, a corresponding equipment was built in the model blast furnace, Figure 1.

Materials were charged in the distributing cylinder of the large bell in a cyclical manner so as to study the character of their distribution. In addition, observations were made with different systems of charging.

The use of the distributing cylinder sharply changed the character of the material distribution at the top, Figure 7.

Charging was done when the charge was descending, the rate of descent corresponding here to the rate of descent in a working furnace at a given blast rate. The volume of the blast given to the furnace was determined by the drop of the pressure at the venturi amounting to 30-60 mm of mercury column corresponding to blast volume of 2.0 cubic meters per minute.

The results of the measurements have shown that the redistribution of the materials at the top is less pronounced with the new charging device than with the old one. Only in case of pulverulent ores some redistribution was noted; the ore lodged in the peripheral ring when the ridge of fines was close to the outer wall, Figure 6A, and in the axial zone when the ridge was found near the inner wall, Figure 6Б. When the ridge was in the middle, the redistribution of the ore fines was but slight, the angle of repose being 20°.

Lump materials did not change their position under the influence of the gas stream, and the angles of repose were close to the natural ones.

Materials	Coke	Sinter	Pulverulent ore	Sized ore	Limestone
Angle of repose when charged with conventional charging device.	27°	18°	7°	24°	25°
Same, with new device and on peripheral ring	-	28	17	23	28
Same, in the axial zone	-	28	23	29	28

The use of the new charging device permits to exert a desired effect on the structure of the column of the materials to be smelted at the beginning of its formation, change the distribution of the materials according to size in the column of the charge and correspondingly control the direction of the gaseous stream (by shifting the ridge in the distributing cylinder). In Figure 8 is shown the distribution of the materials at the stock line after a careful removal of the distributing cylinder.

The changes in the distribution of the materials according to their size was investigated by sampling with the help of quartz tubes 60 mm diameter inserted radially into the charge of the top. In Figure 9 are shown samples, taken as an example, characterizing the distribution of the materials inside of the column with the ridge being located next to the outside wall, Figure 6A.

As a result of the reduction of the surface of the stock line through the use of the cylinder, the influence of the increased gas velocity on the distribution of the materials appears to be much smaller than in the presently employed devices and, particularly, when the ridge of the materials is in the middle, Figure 7 Б, test Ж, middle drawing.

It appears that comparatively fine fractions segregate under the distributing cylinder which increases the interstices between lumps in the peripheral and central areas; on this account the total velocity of the gas discharge at the surface of the columns is somewhat lowered.

The application of the charging device of the new design permitted to eliminate the phenomenon of the materials redistribution at the top and to obtain a uniform distribution of the materials in the column of the charge.

Conclusions

The charging device presently proposed meets all requirements of the charging devices and has the following advantages:

a. a sufficiently uniform distribution of the materials in concentric areas of the furnace cross section in respect to their size and chemical composition;

b. possibility of maintaining a constant optimum materials distribution along the radius of the furnace;

c. the lack of necessity for sealing the rotary distributer;

d. no need for providing distributing stations and panels for establishing the working program for the charge distributer;

e. simplification of controlling the blast furnace operation, since the change of the size of rounds, of charging practice, of stock level, of the charge distributer program become superfluous;

f. possibility of an automatic control of the blast furnace.

The proposed charging device is designed for a blast furnace having 1386 cubic meters working volume. The advantages of the device will be increased on its being installed on blast furnaces with a volume of 2000 meters and more. The new design will facilitate running the furnace, will permit forcing its operating while maintaining uniform operation and more complete utilization of the energy of the gases, as a result of which a larger production and a lower coke rate can be expected.

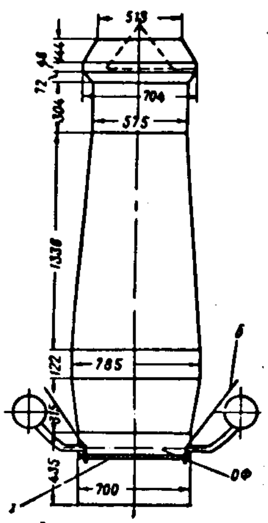

Рис. 1. Модель доменной печи с уменьшением линейных размеров в 10 раз:
а — диск для опускания шихты; б — тросик; ОФ — ось фурм

Figure 1. Model of a blast furnace having its dimensions on a 10:1 scale.
- a. disc for lowering the charge
- б rope
- ОФ axis of the tuyere

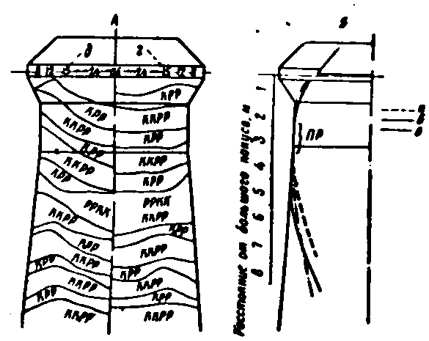

Рис. 2. Распределение материалов в модели доменной печи при системе загрузки ККРРх КРРх (А) и траектории падения материалов с большого конуса (Б) при различных системах загрузки:
а — РРРРхКККх; б — ККРРхКРРх; в — РРККхРРКх; г — распределение материалов с дутьем; д — то же, без дутья (ПР — пояс рикошетирования на уровне 1.5–5.0 м от нижнего положения большого конуса)

Figure 2. Distribution of the materials in the model of a blast furnace using the CCOOxCOOx system of charging (A) and trajectory of the falling of the materials from the big bell (Б) with different systems of charging.
Ordinates: distance from the large bell, meters
- а - OOOOxCCCx
- б - CCOOxCOOx
- в - OOCCxOOCx
- г - distribution of the materials with the blast
- д - same, without blast
- ПР - reflection region at the level of 1.5-5 meters from the bottom position of the large bell.

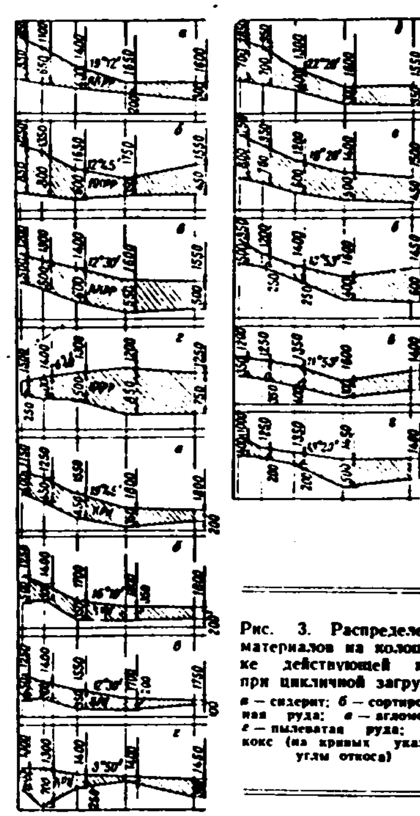

Рис. 3. Распределение материалов на колошнике действующей печи при цикличной загрузке:
а — сидерит; б — сортированная руда; в — агломерат; г — пылеватая руда; д — кокс (на кривых указаны углы откоса)

Figure 3. Distribution of the materials at the top of an operating furnace using cyclical charging.
- а - siderite
- б - sorted ore
- в - sinter
- г - pulverulent ore
- д - coke

(on the curves are marked angles of repose)

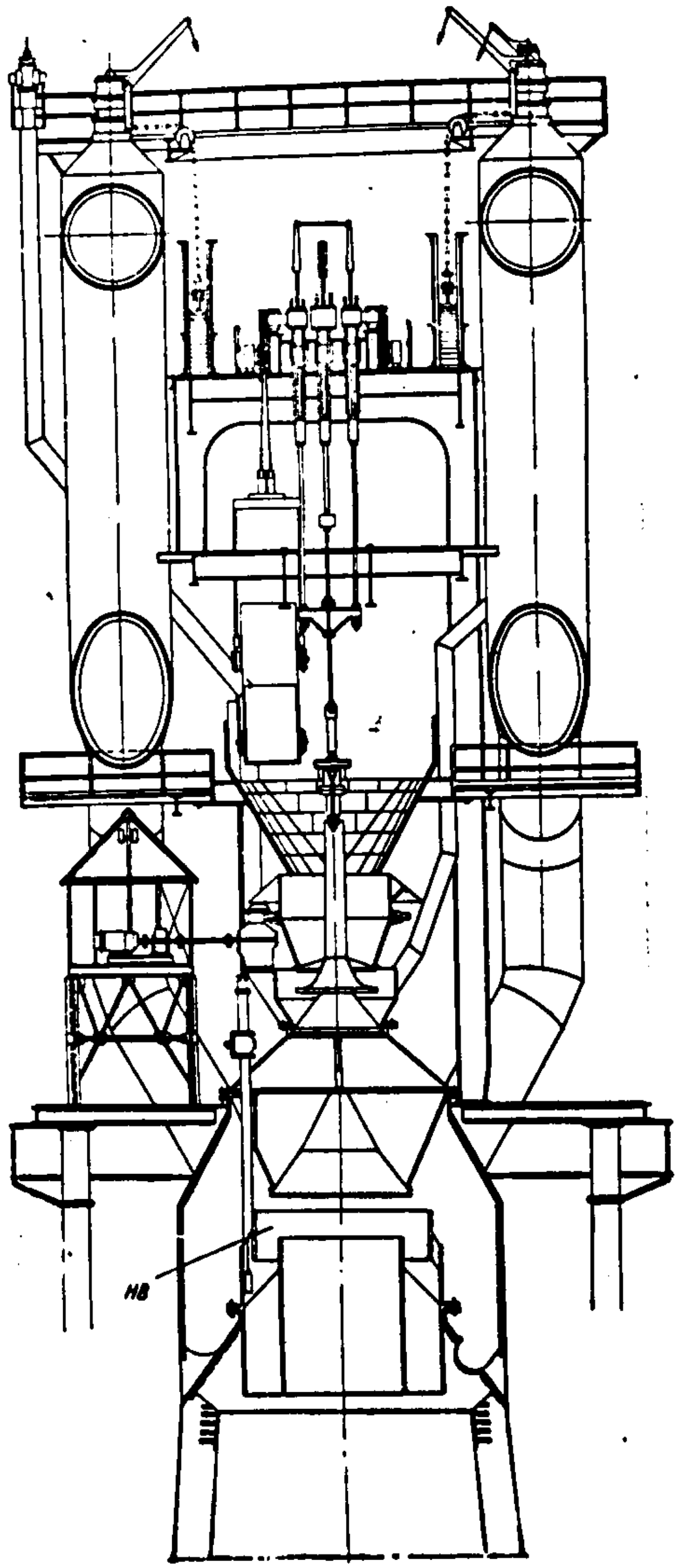

Рис. 4. Засыпное устройство новой конструкции

Figure 4. Charging equipment of the new design.

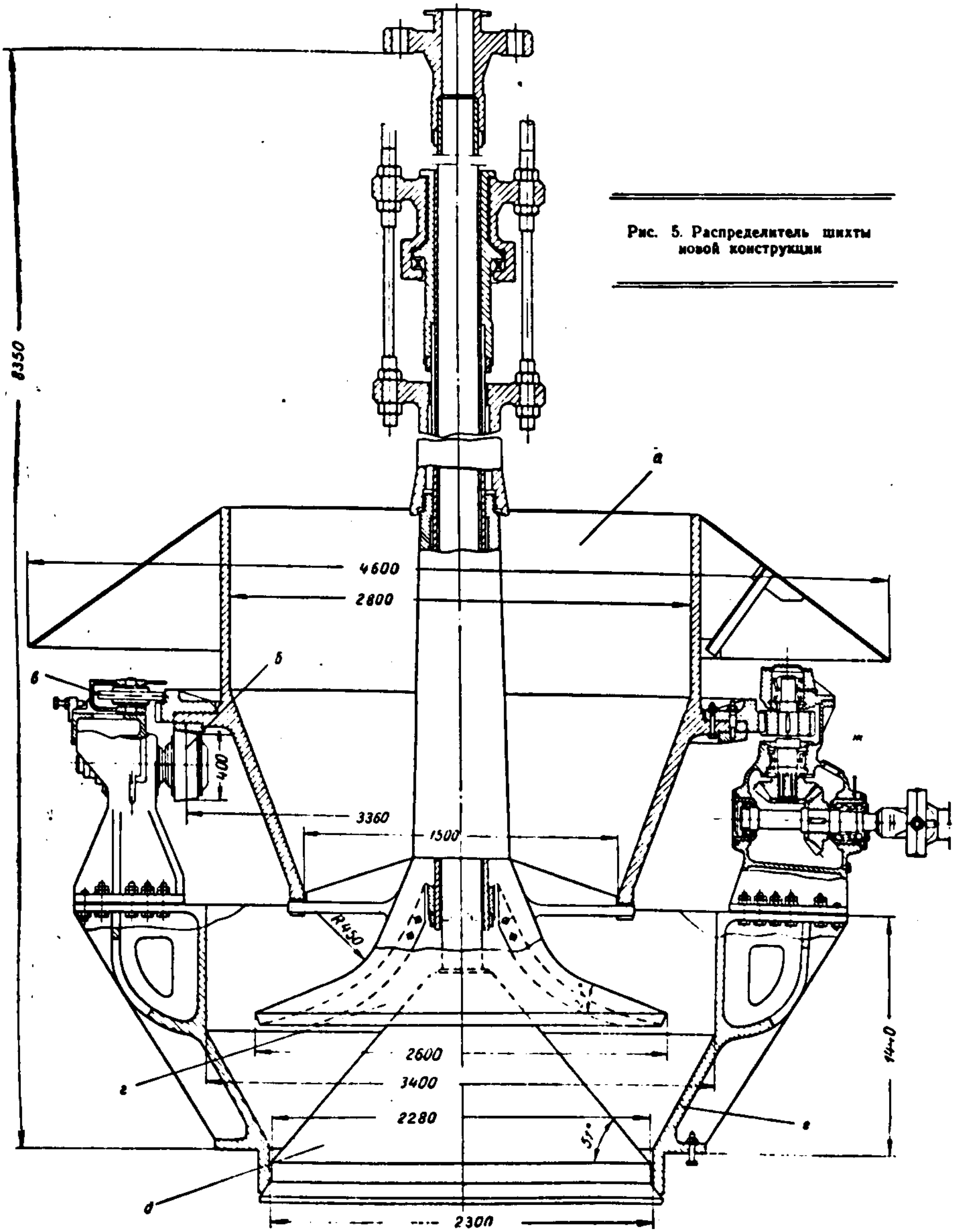

Figure 5. Charge distributor of the new construction.

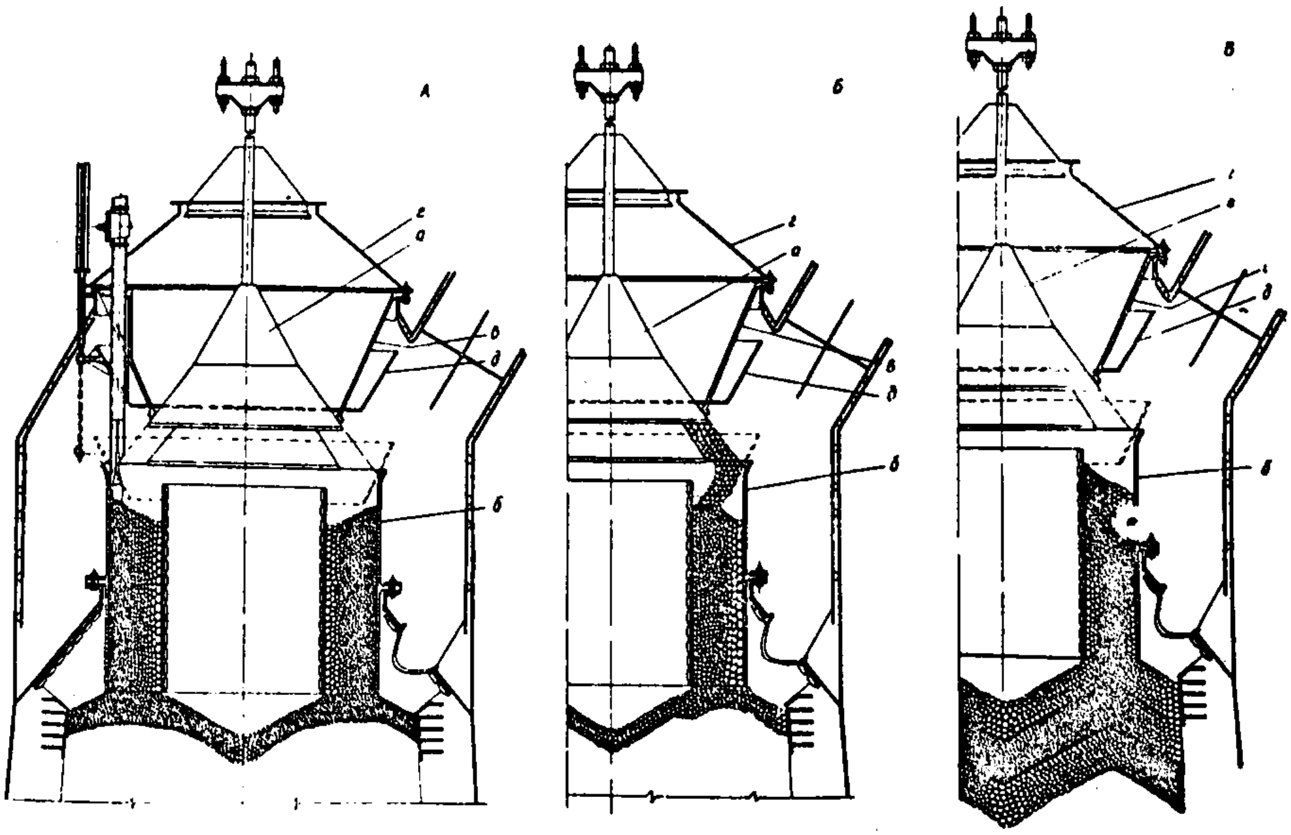

Рис. 6. Засыпной аппарат новой конструкции:
А — распределение материалов при верхнем положении направляющей воронки; Б — то же, при нижнем положении воронки; В — распределение материалов в печи при чередовании положений воронки

Figure 6. Charging device of the new design

A - distribution of the materials with the upper position of the guiding hopper

Б - same, with the bottom position of the guiding hopper

B - distribution of the materials in the furnace with the alternating position of the hopper

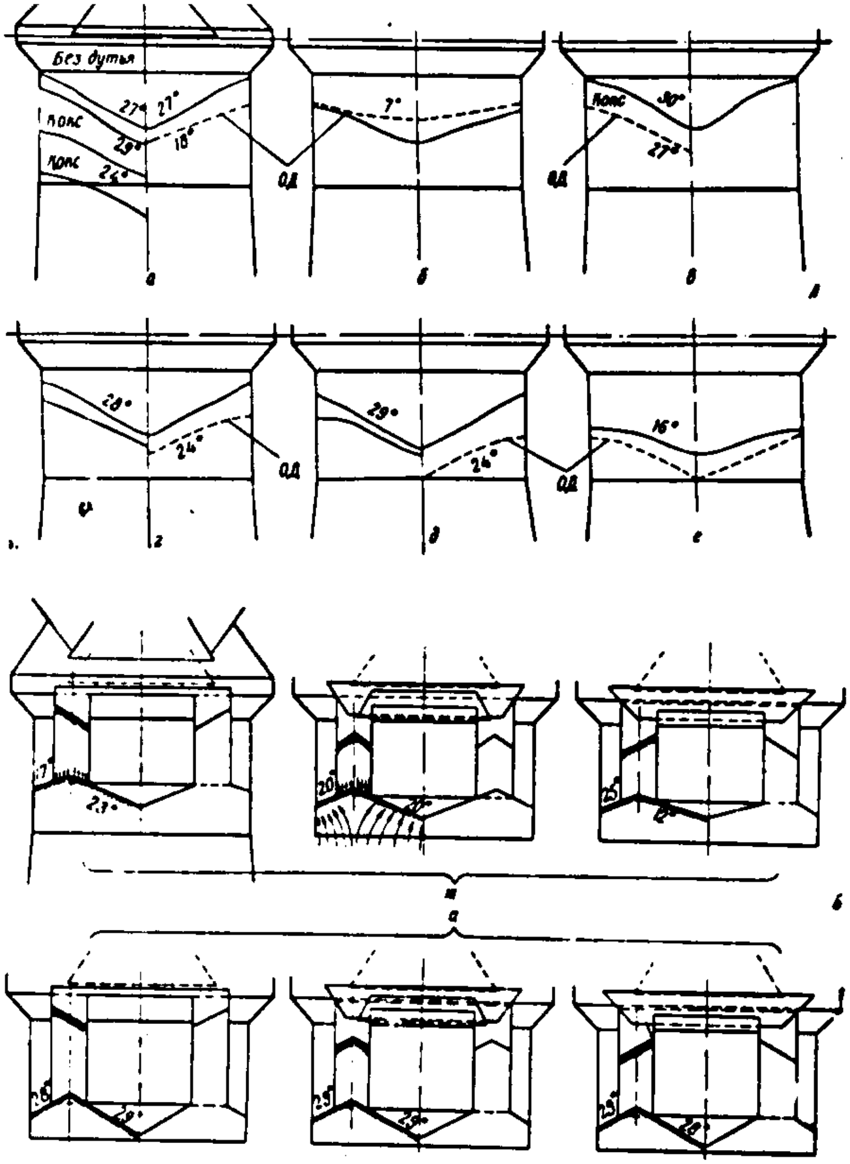

Рис. 7. Сопоставление распределения материалов при загрузке обычным засыпным аппаратом (*А*) и предлагаемым (*Б* — с направляющей воронкой и без нее):

а — агломерат (крупный); *б* — сортированная мелкая (пылеватая) руда; *в* — кокс; *г* — сидерит; *д* — сортированная (крупная) руда; *е* — агломерат (мелкий); *ж* — пылеватая руда; *ОД* — на дутье после опускания шихты (у кривых — углы откосов)

Figure 7. Comparison of the materials distribution when using a conventional charging device (A) and the proposed one (Б - with guiding hopper and without it)

- а - sinter (coarse)
- б - sorted fine ore
- в - coke
- г - siderite
- д - sorted (lump) ore
- е - sinter (fine)
- ж - pulverulent ore
- ОД - on blast after lowering the charge (angles of repose are given at the curves)

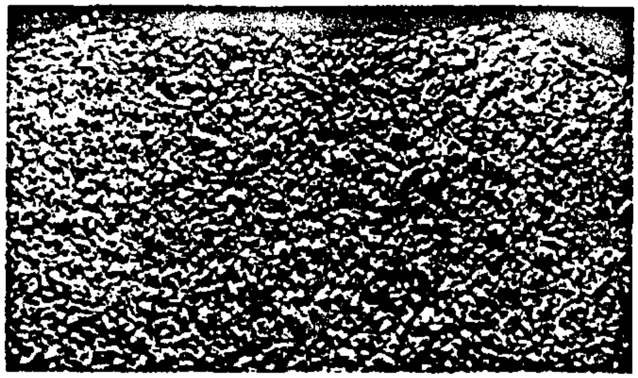

Рис. 8. Поверхность засыпи на модели печи (после снятия распределительного цилиндра)

Figure 8. Surface of the charge in model furnace (after the removal of the distributing cylinder).

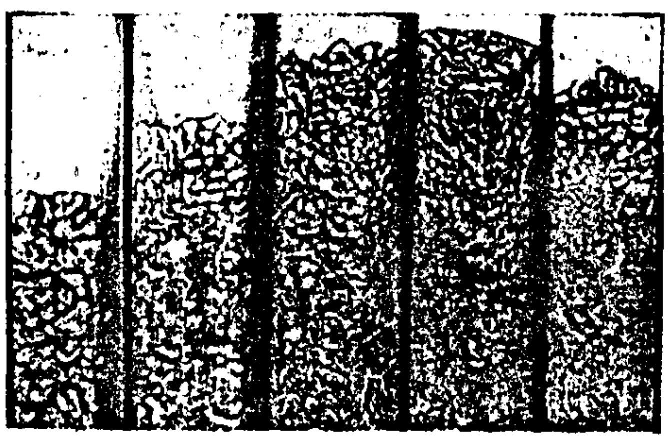

Рис. 9. Пробы шихты, отобранные по радиусу колошника при расположении гребня у наружной стенки цилиндра (рис. 6, А)

Figure 9. Samples of the charge taken in the radial direction at the top with the ridge next to the outer wall of the cylinder. (Figure 6A)